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Stink Bugs on Seed Alfalfa in Southern Arizona

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INTRODUCTION

Certain stink bugs are important pests of alfalfa grown for seed in southern Arizona. An investigation of them was conducted at Tempe, Ariz., over the period 1935 through 1949. From 1935 until 1944 the habits of the insects were studied, with emphasis on ecological factors essential to their control. In 1945 emphasis was shifted to control of the bugs with insecticides. Because of its greater abundance and economic importance, more work was done with *Chlorochroa sayi* Stål than with the other species found.

All laboratory observations were made at Tempe. Most of the field investigations were conducted in the irrigated Salt River and Buckeye Valleys in Maricopa County, which are surrounded by large areas of desert or range land. In these valleys the elevation ranges from 800 to 1,300 feet above sea level, the average annual mean temperature from 68° to 71° F., and the average

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annual rainfall from 3.5 to 8.5 inches.

The first alfalfa crop is pastured or cut for hay, and the main seed crop is usually produced on the second growth. This seed crop as a rule is started between April 15 and May 1 and harvested between July 10 and 25. A second seed crop, which is harvested about September 15, is occasionally produced on the growth that follows harvest of the main crop. Sometimes two, or even three, hay crops precede the seed crop. In most years immature alfalfa seed is present in some fields from about the middle of June to the middle of September.

CHARACTER OF INJURY

Stink bug adults and nymphs injure alfalfa seed by removing the liquid contents while the seeds are immature. The bug inserts its beak through the seed pod into the interior of the seed to obtain the juices. The damaged seed collapses into a flattened shell, which soon shrivels, dries, turns brown, and is usually blown out with the chaff during threshing. A round and sometimes slightly depressed scar develops at the puncture. Damage to the seed is not recognizable from a field inspection or an external examination of the seed pod. No evidence of economic damage to the growth of alfalfa by stink bugs was observed under normal field conditions, but heavy concentrations of the bugs in small field cages severely reduced the growth.

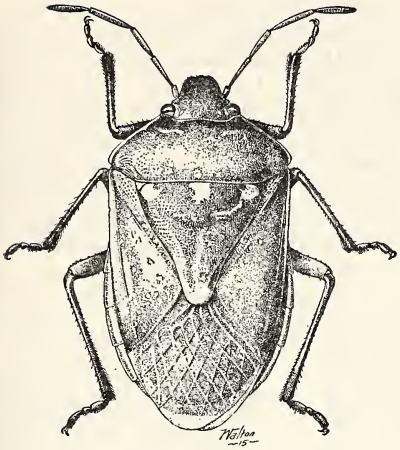
SPECIES FOUND AND RELATIVE ABUNDANCE

The relative abundance of different species of stink bugs was determined from samples collected by sweeping with a standard 15-inch insect net or by making counts on unit areas. These collections are summarized in table 1.

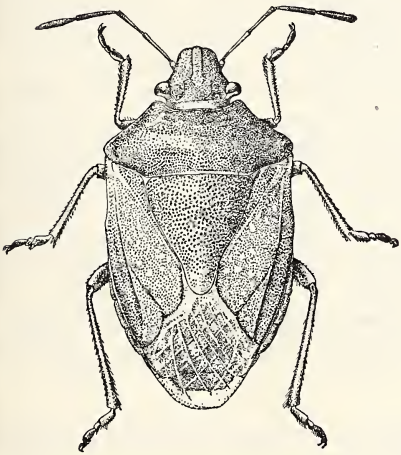
Chlorochroa sayi, known as the Say stink bug, was by far the most numerous and important species throughout the period. *Euschistus impictiventris* Stål, often called the brown cotton bug, was second in abundance, and *Thyanta custator* (F.), sometimes called the red-shouldered plant bug, third. Two species of little economic importance, *C. ligata* (Say) or the conchuela, and *Acrosternum hilare* (Say) or the green stink bug, together comprised less than 1 percent of the population.

TABLE 1.—*Stink bugs collected on seed alfalfa in southern Arizona, 1936–43*

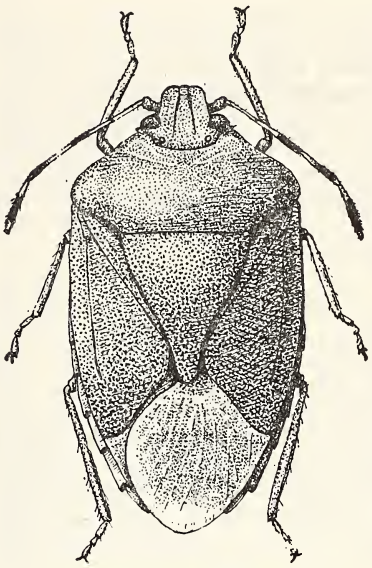
Year	Net strokes	Average stink bugs taken per net stroke	*Chlorochroa sayi*	*Euschistus impictiventris*	*Thyanta custator*	*Acrosternum hilare* and *Chlorochroa ligata*
	Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*
1936	28, 550	0. 06	71	24	4	1. 2
1937	25, 360	. 10	67	17	15	1. 1
1938	90, 960	. 06	86	11	2	. 3
1939	77, 400	. 04	71	13	13	2. 4
1940	62, 400	. 09	77	17	6	. 01
1941	24, 500	. 06	74	17	8	. 6
1942	34, 500	. 01	65	26	9	. 5
1943	33, 300	. 19	73	24	3	. 01
Average		. 07	73	18. 6	7. 6	. 8



The Say stink bug.



The red-shouldered plant bug.



The green stink bug.

Chlorochroa sayi, a widely distributed species in the Western States from Mexico to Canada, was taken in all Arizona areas surveyed. This species, formerly known as the grain bug, was described by Caffrey and Barber (*1*) in 1919. The adults vary considerably in size and color. In the Arizona collections the females averaged 13.3 mm. in length and the males slightly less. The color ranges from dark green in spring to light green in midsummer and to olive and reddish brown in fall and winter. The most characteristic markings are three large pale or yellowish callouses on the anterior border of the scutellum.

Chlorochroa ligata was found in small numbers in all the principal alfalfa seed-growing areas of southern Arizona. It has been reported mainly from northern Mexico, Texas, and New Mexico, but also occurs in California, Colorado, and Utah. This species was described by Morrill (*4*) in 1910. The adults are slightly larger than those of *C. sayi*. Females collected in Arizona averaged 13.8 mm. in length; the males were a little smaller. The color varies widely, from dull olivaceous or ashy gray to greenish, purplish pink, or reddish brown. The most characteristic markings are an orange-to-red band along the lateral margins of the thorax and the basal one-third to two-thirds of the costal margins of the wing corium, and a spot of the same color at the tip of the scutellum.

Euschistus impictiventris has been taken in irrigated districts throughout southern Arizona, and its range extends from Texas to

Utah, Nevada, and southern California. The adults are slightly smaller than those of *Chlorochroa sayi* or *C. ligata*, averaging 12 mm. in length. The yellowish-brown color of the adult is remarkably uniform. The head is elongate, and the lateral angles of the pronotum are prominent and often sharply pointed.

Thyanta custator is well-distributed in Arizona, as well as over the United States generally. It is the smallest of the five species of stink bugs included in these studies. The adults range from 9 to 11 mm. in length. They are green, but the shade varies greatly in different individuals. The antennae are usually reddish brown. On some specimens a narrow reddish band joins the lateral angles of the pronotum, and the margins, medial line, and apex of the scutellum frequently have pale, light-yellowish, or reddish markings. In Arizona these markings are usually absent during midsummer. The ventral surface of the body is pale. The lateral angles of the pronotum are rather prominent but not sharply pointed.

Acrosternum hilare has been reported from both North and South America, and its range in the western part of the United States includes Arizona, California, Colorado, Montana, New Mexico, Texas, and Utah. In southern Arizona it was taken only in the Salt River Valley in Maricopa County. *A. hilare* is a large light-green species about 15 mm. long. The apical antennal joints and five marginal spots on the connexivum are black, and the head, pronotal, and corial margins are often lined with yellow. The lateral angles of the pronotum are prominent.

DAMAGE TO ALFALFA-SEED CROPS

During the seven seasons 1937 through 1943 nearly 800 samples of alfalfa seed from three areas in south-central and southwestern Arizona were examined for damage by stink bugs. The results of these examinations are summarized in table 2. The average seed damage in the three areas was approximately 6 percent. Damage was highest in the Buckeye Valley and lowest in the Yuma Valley. It varied greatly in different years, ranging from less than 1 percent in 1942 to 15 percent in 1938.

TABLE 2.—*Damage by stink bugs to alfalfa seed in three areas of southern Arizona, 1937–43*

Year	Salt River Valley		Buckeye Valley		Yuma Valley	
	Samples examined	Damage	Samples examined	Damage	Samples examined	Damage
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
1937	13	11	43	15	12	6
1938	28	11	90	15	32	12
1939	16	2	45	6	6	4
1940	38	4	66	3	—	—
1941	23	5	72	6	—	—
1942	22	0. 2	44	2	84	1
1943	36	3	53	3	73	3
Total or average	176	5	413	8	207	4

Although average seed damage did not exceed 15 percent in any year, damage in individual fields was much higher in some years. For example, in 1937 seed damage was 22 percent in some fields in the Buckeye Valley, 36 percent in the Arlington area, 28 percent in the Yuma Valley, and 77 percent in the Safford area.

HOST PLANTS

The stink bugs that attack alfalfa also feed on many other cultivated and uncultivated plants. In general, the host plants are about the same for *Chlorochroa sayi*, *C. ligata*, *Thyanta custator*, and *Euschistus impictiventris*. The first three species apparently prefer to feed on the immature seed, but *E. impictiventris* feeds readily on both the vegetative growth and the seed. *Acrosternum hilare* was collected only from alfalfa, mixture of alfalfa and small grains, trees, and shrubs.

Extensive collections and observations were made in southern Arizona to determine the host-plant range of *Chlorochroa sayi*, the species most important to growers of alfalfa seed.

Crops severely damaged are alfalfa, barley, seed beets, cotton, grain sorghum, oats, okra, squash, and wheat. Crops occasionally attacked are beans, corn, cowpeas, peas, spinach, tomato, seed turnips, and vetch. Summer cypress (*Kochia scoparia*), an ornamental, is sometimes attacked.

The most important uncultivated host plants are as follows:

Alfileria (*Erodium cicutarium*)
Australian saltbush (*Atriplex semibaccata*)
Canaigre (*Rumex hymenosepalus*)
Carelessweed (*Amaranthus palmeri*)
Glovemallow (*Sphaeralcea* spp.)
Mallow (*Malva parviflora*)
Nettleleaf goosefoot (*Chenopodium murale*)
Sisymbrium irio
Trianthema portulacastrum

Nymphs or adults of *Chlorochroa sayi* were also observed on the following uncultivated plants:

Brittlebush (*Encelia farinosa*)
Bur-clover (*Medicago hispida*)
Bur-sage (*Franseria deltoidea*)
Cattle-spinach (*Atriplex polycarpa*)
Chinese pusley (*Heliotropium curassavicum* var. *osculatum*)
Common mesquite (*Prosopis juliflora* var. *velutina*)
Creosotebush (*Larrea tridentata*)
Curlyleaf dock (*Rumex crispus*)
Desert-sunflower (*Geraea canescens*)
Fourwing saltbush (*Atriplex canescens*)
Fragrant-bitterweed (*Actinea odorata*)
Iodinebush (*Allenrolfea occidentalis*)
Johnson grass (*Sorghum halepense*)
Pigweed (*Chenopodium* sp.)
Prickly lettuce (*Lactuca serriola*)
Quailbrush (*Atriplex lentiformis*)
Russian-thistle (*Salsola pestifer*)
Wheelscale saltbush (*Atriplex elegans*)
Wild oats (*Avena barbata*)
Gaura parviflora
Tidestroma oblongifolia

The seasonal sequence of the bugs in substantial numbers on various plants is about as follows: Weeds, February 15 to April 15; sugar beets, April 15 to June 15; small grains, April 15 to May 31; alfalfa, June 15 to September 15; cotton, July 1 to October 15; and grain sorghums, September 1 to October 15.

LIFE-HISTORY STUDIES

Rearing Methods

Life-history studies were conducted in an outdoor insectary. The cage found most adaptable for these studies was a glass cylinder 2½ inches in diameter by 12½ inches long, closed at each end with cheesecloth held in place by rubber bands. It was taped to a wooden stake and held in a vertical position by inserting the lower end of the stake into a hole in a block of wood which rested on the insectary table. A glass test tube filled with water was inserted in a second hole in the wooden block directly under the center of the cage. Several branches of food plants were placed in the cage, their stems extending through a hole in the lower cheesecloth into the water in the test tube. In this manner the food could be kept succulent for 1 to 3 days, depending on the temperature.

Overwintering adults were collected early in the spring. Laboratory-reared stink bugs were used for the succeeding generations. A male and a female were placed in each cage. When available, alfalfa bearing immature seed was supplied as food. Sometimes, however, it was necessary to use alfalfa of less mature growth or branches of *Sisymbrium irio*, a species of uncultivated mustard. Egg clusters were removed from the cages soon after they were deposited, to prevent the parent bugs from sucking the liquid contents from the eggs. The first cluster from each generation was placed in a separate cage for use in studies of later generations. Soon after hatching, the nymphs from each cluster were divided into several lots to increase the probability of rearing some of them to maturity. Adults were usually retained in their original cages for completion of longevity records.

Egg Deposition

Females confined in cages deposit their egg clusters on the leaves and stems of the plants provided for food or on other surfaces, frequently on the cheesecloth ends of the cages. The eggs are arranged in two or more parallel rows. They are held together and to the supporting surface by a viscous fluid, which soon hardens. Occasionally there are two or three layers of eggs in a cluster; then only the eggs in the outer layer hatch. The numbers of eggs and rows in clusters deposited by the different species are given in table 3. The average number of eggs per cluster was similar for all species except *Euschistus impictiventris*, which laid much smaller clusters.

The number of eggs laid per female and the length of the oviposition period for *Chlorochroa sayi*, *Euschistus impictiventris*, and *Thyanta custator* are given in table 4. The average number of eggs laid per female varied greatly between these species, but there was little difference in the average length of the oviposition period.

Incubation

Incubation records obtained on eggs from five species of stink bugs, segregated as to daily mean temperature ranges during the incubation period, are shown in table 5.

TABLE 3.—*Numbers of eggs in clusters laid by different species of stink bugs*

Species	Number of clusters	Average rows of eggs per cluster	Eggs per cluster	
			Average	Maximum
Chlorochroa sayi	76	4. 6	28. 4	77
C. ligata	60	5. 4	32. 4	69
Euschistus impictiventris	55	3. 5	17. 6	32
Thyanta custator	107	4. 5	27. 5	61
Acrosternum hilare	15	5. 6	30. 0	[1] 71

[1] Two layers.

TABLE 4.—*Eggs laid per female and oviposition period of three species of stink bugs*

Species	Females	Eggs per female		Oviposition period	
		Average	Maximum	Average	Maximum
	Number	*Number*	*Number*	*Days*	*Days*
Chlorochroa sayi	20	151	526	26	47
Euschistus impictiventris	20	60	107	24	30
Thyanta custator	28	118	334	29	34

The mean temperature ranges corresponded roughly with those of certain months of the year at Tempe, as follows: 60°–70° F., April and October; 70°–80°, May; 80°–90°, June, July, August, and September; and 90°–100°, July (in occasional years). The incubation period for eggs of all species decreased as the temperature increased. This is in agreement with observations on eggs of *Chlorochroa sayi* made by Caffrey and Barber (*1*) in New Mexico and by Patton and Mail (*5*) in Montana. The average incubation period for eggs of *Acrosternum hilare* at 70°–80° and 80°–90° was several days longer than for eggs of the other species (table 5). At summer temperatures, 80°–90°, the average incubation time was about 5 days. At temperatures approximating those early in the spring and in October, 60°–70°, the average period was about twice as long, ranging from 9 to 12 days. The shortest period for individual egg clusters was 3 days, for *Chlorochroa ligata* and *Thyanta custator*, and the longest was 15 days, for *Euschistus impictiventris*.

HATCHING

Hatching tests with eggs of *Chlorochroa sayi* were conducted each year from 1936 through 1942. The egg clusters were collected in alfalfa fields, brought to the screened insectary, and kept in cardboard boxes until hatching was completed. Table 6 shows the percentage of eggs that hatched each year. Eggs that had been parasitized, damaged or partly destroyed by predators, or punctured by adult stink bugs were not included in these computations.

TABLE 5.—*Incubation period for stink bug eggs at different temperatures*

Species	Range of daily mean temperatures	Egg clusters	Time required for incubation	
			Range	Average
	°F.	Number	Days	Days
Chlorochroa sayi	60–70	6	8–12	10. 0
	70–80	20	4–8	6. 2
	80–90	8	4–7	5. 1
C. ligata	60–70	2	9–9	9. 0
	70–80	14	5–9	6. 6
	80–90	20	3–8	4. 8
	90–100	3	3–4	4. 5
Euschistus impictiventris	60–70	9	6–15	11. 6
	70–80	6	4–8	6. 0
	80–90	10	4–6	5. 2
	90–100	1	4–4	4. 0
Thyanta custator	60–70	1	12–12	12. 0
	70–80	12	3–10	5. 6
	80–90	15	3–6	4. 6
	90–100	6	3–6	4. 1
Acrosternum hilare	60–70	4	9–13	11. 2
	70–80	6	7–10	9. 5
	80–90	1	7–7	7. 0

TABLE 6.—*Hatch of field-collected eggs of* Chlorochroa sayi, *1936–42*

Year	Eggs	Hatched
	Number	Percent
1936	4, 606	57
1937	11, 682	70
1938	32, 517	57
1939	5, 820	61
1940	7, 671	69
1941	476	53
1942	2, 779	68
Average		62

NYMPHAL DEVELOPMENT

Nymphal development was observed in cage tests carried out in 1936, 1937, and 1938. Eggs of *Chlorochroa sayi*, *C. ligata*, *Euschistus impictiventris*, and *Thyanta custator* were incubated and the surviving nymphs reared to the adult stage at three average daily mean temperatures. A single lot of *Acrosternum hilare* eggs was incubated, and the surviving nymphs were carried through to the adult stage at an average daily mean temperature of 75° F. Table 7 shows the results of these tests. The rate of development through the egg and nymphal stages was more rapid at the higher temperatures.

At similar average daily mean temperatures, 85°–87° F., which closely approximate those at Tempe from late June to mid-September, the average time required to develop through the egg and nymphal stages was approximately 28 days for *Chlorochroa sayi*, 29 days for *Thyanta custator*, 33 days for *C. ligata*, and 36 days for *Euschistus impictiventris*. At average daily mean temperatures of 73° to 76°, which approximate May daily mean temperatures at Tempe, the period of development was approximately 45 days for *C. sayi*, 38 days for *T. custator*, and 35 days for *C. ligata* and *E. impictiventris*. Increases in average daily mean temperature from 85°–87° to 91°–92° hastened the development of *C. ligata* and *T. custator*, but not that of *C. sayi*. At comparable temperatures the de-

TABLE 7.—*Average time required for incubation and nymphal development of several stink bug species at different temperatures, 1936–38*

Species and average daily mean temperature (° F.)	Stink bugs	Egg stage	Nymphal stage					
			First	Second	Third	Fourth	Fifth	Total
Chlorochroa sayi:	*Number*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*
73	10	10	6	7	5	7	10	35
85	11	5	3	5	4	4	7	23
91	2	6	5	3	4	6	5	23
C. ligata:								
76	6	7	5	5	5	6	7	28
87	9	6	4	4	5	5	9	27
92	5	5	5	4	4	5	7	25
Euschistus impictiventris:								
67	2	8	6	6	7	10	13	42
76	5	6	5	5	6	6	7	29
86	6	5	6	5	6	6	8	31
Thyanta custator:								
75	5	5	6	6	7	6	8	33
85	13	5	4	5	5	5	6	25
91	4	5	4	4	4	3	4	19
Acrosternum hilare:								
75	5	7	7	6	8	11	22	54

velopmental period of *Acrosternum hilare* was 16 to 26 days longer than that of the other species.

Nymphal mortality in cages was generally high, but varied considerably between species and stages. It was highest for *Euschistus impictiventris*, intermediate for *Chlorochroa sayi* and *C. ligata*, and lowest for *Thyanta custator*. It was much higher for nymphs in the second, third, and fourth stages than for those in the first and fifth stages.

MATING AND EGG LAYING

Mating and egg laying usually begin within 2 weeks after stink bugs reach the adult stage, but the interval varies widely under different weather conditions and to some extent with different species, as shown here for caged adults of two species at Tempe.

	Days required for—	
	Premating	First mating to first oviposition
Chlorochroa sayi	3–15	1–15
Thyanta custator	4– 8	3–15

The females frequently alternate mating and egg laying, but they may deposit two or more egg clusters between matings or mate two or more times between egg depositions. The consecutive matings or egg depositions may occur within comparatively short periods. Females of *Chlorochroa sayi* under observation laid as many as 10 egg clusters and mated six times over a period of 47 days; those of *Thyanta custator* laid 10 egg clusters and mated eight times in 34 days. Mating usually lasted 2 hours or longer, and in two matings of

Euschistus impictiventris it continued without apparent interruption for 2 days.

Longevity

Data were obtained on the total time necessary for *Chlorochroa sayi* and *Thyanta custator* to complete their life cycles. In summer, at a daily mean temperature of approximately 85° F., each species required slightly less than 5 weeks. In spring and fall, at a daily mean temperature of 73°–75°, *C. sayi* required about 8 weeks and *T. custator* about 7 weeks. Both species developed slightly faster in the field than in the insectary cages. Between the latter part of March and the latter part of October, average daily mean temperatures at low elevations in southern Arizona are sufficiently high for the development of five generations of *C. sayi* and *T. custator*, and probably of *C. ligata* and *Euschistus impictiventris*.

Stink bug adults live for long periods when provided with ample fresh food. Average and maximum longevities of samples of adults of four species are given in table 9. Adults of all species usually lived 40 to 60 days in spring and summer, but some overwintering adults lived 7 to 9 months. When the temperature was 90° F. or above, they usually died within 3 to 5 hours if not furnished suitable food.

FIELD OBSERVATIONS

At low elevations in southern Arizona at least five generations of the stink bugs affecting alfalfa seed develop each year. There is considerable overlapping of generations. The time and rate of development and activity depend largely on weather conditions, especially maximum daily temperatures. Stink bugs are seldom active below 60° F., and normal activity does not usually begin until the temperature has reached 70°.

Winter Habitats and Activities

In southern Arizona stink bugs pass the winter in the adult stage. Apparently they do not truly hibernate, at least in the warmer valleys. Periods of inactivity under shelter are usually alternated with periods of limited activity. The number and duration of these periods vary considerably with weather conditions. Some adults and late-stage nymphs may go under shelter as soon as the nights become cool, sometimes by the latter part of Sep-

Table 9.—*Longevity of stink bug adults*

Species	Sex	Adults	Length of life	
			Average	Maximum
		Number	*Days*	*Days*
Chlorochroa sayi	Male	22	70	246
	Female	29	66	225
C. ligata	Male	9	59	217
	Female	9	61	187
Euschistus impictiventris	Male	15	97	275
	Female	17	106	274
Thyanta custator	Male	24	52	83
	Female	27	63	108

tember, and in some years the winter quarters may not be completely abandoned until the middle of April. The nymphs either die or transform into adults in the fall. Most overwintering adults are inactive late in December, in January, and early in February, but some individuals may become active on the warmer days during this period. *Euschistus impictiventris* and *Thyanta custator* are more active than *Chlorochroa sayi* during the cooler parts of the year.

During the winter stink bug adults may be found in various protected situations. They are usually near the soil surface under low-growing plants or plant debris. Weedy and grassy fence rows, roadsides, and ditchbanks are important winter habitats in irrigated areas. The favored winter shelter is under the spreading and carpetlike branches of Australian saltbush, a common plant in the cultivated districts of southern Arizona, particularly along field margins. From 200 to 300 adults per square foot of soil surface were often found under this plant. Small depressions or pockets in the soil under the saltbush plants frequently contained from 15 to 25 *Chlorochroa sayi* adults embedded in soft earth or leafmold. However, most of the bugs remained above the soil surface, sheltered only by the branches or litter of plants among which they were embedded.

Emergence of Adults From Winter Shelter

It is usually early March before substantial numbers of adults leave their winter shelter and resume normal and fairly continuous activity on growing plants. This movement to spring host plants may require several weeks.

Mating may take place at a temperature as low as 58° F., as observed in the case of one pair of *Thyanta custator*, but it does not become common until the temperature reaches 75° or above. Females do not begin laying eggs until 2 to 3 weeks after leaving winter shelter. Normally there is little oviposition before March 15. It has been observed in the field at temperatures ranging between 68° and 106°, being accelerated by rising temperatures within this range. Under exceptionally favorable conditions, feeding, mating, and egg laying may start very early in the year. Freshly laid eggs have been collected late in January in the Yuma Valley, and early stage nymphs of *Chlorochroa sayi* were found on January 20 in the Salt River Valley and on February 23 in the Yuma Valley.

Spring Activities

Uncultivated, or weed, host plants are preferred by overwintering adults when they leave their winter shelter. *Sisymbrium irio*, mallow, and nettleleaf goosefoot are usually abundant along field margins and in waste land. They may also be present in cultivated land, particularly in citrus groves or fields where winter or early spring vegetable crops are grown. The weeds bloom and produce seed over a long period, from mid-January to late April or early May. Most of the overwintering females lay their eggs on this weed growth, and the first-generation nymphs, feeding mainly on the immature seed, grow to maturity on it. Large numbers of *Chlorochroa sayi* adults are frequently found early in the spring concentrated in fairly small areas on these and other weeds.

Stink bug adults of the first generation normally begin to appear late in April or early in May, but have been found as early as April 15 in the warmer localities in the Salt River Valley. At this time the

winter and early spring growths of weed host plants are drying up and becoming unsuitable for further feeding. Therefore, most of the adults soon move into fields of alfalfa, small grains, sugar beets, and other crops.

Preferred Egg-laying Sites

The eggs of stink bugs may be deposited on many objects, but most of them are laid on living plants. Early in the spring they are most often placed on the under surface of the leaves of weeds. Later in the season they may be found on any part of the alfalfa plant above ground, but usually on the leaves and racemes of the top third of the plant. Little difference can be noted in the number of clusters laid on the upper and lower surfaces of the leaves. Eggs of *Euschistus impictiventris* are usually located lower on the plant than are those of the other species.

Migration and Seasonal Sequence on Different Hosts

This migration to cultivated crops may be of two types. In south-central and southwestern Arizona most of the stink bugs that damage crops apparently develop in the irrigated valleys. The movements are for short distances, from weed hosts along margins of fields or in fields to crops in nearby fields. First-generation, or perhaps overwintering, adults of *Chlorochroa sayi* may also occasionally come into the low irrigated valleys from desert or range land some distance away, for heavy local infestations of *C. sayi* of a uniform but markedly different coloration from others in the same general area have been found.

The second type of migration was observed in the Upper Gila Valley, near Safford and Thatcher, in May 1940. This valley is higher and considerably cooler than the irrigated areas in the south-central and southwestern parts of the State. Large numbers of *Chlorochroa sayi* and smaller numbers of *Euschistus impictiventris* and *Thyanta custator* adults that had developed on alfileria and other range vegetation left the range land when their food plants began to dry up and converged on the small cultivated area in the valley. Alfalfa was not in the seeding stage at that time, but the bugs destroyed practically all the small-grain crops that were in the soft stages of seed development. From 4 to 20 adults were counted on a single head of wheat, and populations averaged from 90 to 177 bugs per net stroke in some of the fields. Similar migrations occurred at about the same time in the Rio Grande Valley near El Paso, Tex., and in the Pecos Valley near Carlsbad, N. Mex.

In the irrigated valleys of southern Arizona most of the stink bugs of all generations except the first lay their eggs, feed, and develop on cultivated crops. Adults of the second generation appear about the middle of June, and those of succeeding generations at 5- to 6-week intervals until the fifth and last generation late in September. From April to October they infest and cause economic damage in various crops. They are usually most numerous in a crop when the seed is immature and in optimum condition for their feeding.

Stink bugs are present in fields of sugar beets and small grains during the latter part of April and most of May, and they may persist in sugar beets until June 15 or July 1. When these crops mature, most of the stink bugs move into alfalfa fields, where they remain during the blooming and seeding periods of the first seed crop, which usually extend to the middle or latter part of July. When the alfalfa seed

matures or the crop is harvested, the bugs may migrate to nearby fields of later maturing seed alfalfa or to fields of cotton. If a second alfalfa seed crop is grown in August or September, it is often heavily infested by stink bugs that move in from late-maturing first-seed-crop alfalfa or from cotton. Alfalfa is an important host plant from June to September, and cotton from July to October. During September and the first half of October many bugs migrate from fields of alfalfa and cotton to fields of grain sorghums. The grain sorghums are usually planted from about June 15 to July 20, and immature seed is available for stink bug feeding from late in August to late in October or early in November.

The adults fly readily from field to field or from crop to crop during spring, summer, and early fall. The nymphs do not fly and usually travel shorter distances. Several nymphal migrations were observed during these investigations. In two of them—one in the Upper Gila Valley on August 12, 1938, and the other in the Salt River Valley on July 23, 1943—nymphs of *Chlorochroa sayi* and *Euschistus impictiventris* were seen leaving mature seed alfalfa, crossing paved highways, and entering cotton fields. Such migrations occur only in the cooler parts of the day. When the ground or pavement gets very warm, as it often does at midday in summer, the nymphs concentrate on posts, weeds, and trash.

Seasonal Abundance on Different Crops

The seasonal abundance of stink bugs varies somewhat from year to year, but usually follows a similar trend in individual crops. In most years the bugs are most numerous in alfalfa during the first half of July, shortly before the main seed crop matures. The peak population on cotton usually occurs during the latter half of August and that on grain sorghums late in September or early in October. Table 10 shows the numbers of stink bugs taken per 100 net strokes on alfalfa in the Buckeye Valley by months during the period 1939–43. The 5-year average population started from a very low point in May, increased rapidly to a peak in July, declined sharply in August, turned slightly upward in September, and then declined to a low figure in November. In 4 years the population reached its peak in July, but in 1942 the peak came in September.

Sex Ratio

Females were more numerous than males in field collections of adults. Of 4,570 individuals of *Chlorochroa sayi* in 17 samples, 57 percent were females. Some of the samples were collected from winter

Table 10.—*Numbers of stink bugs taken per 100 net strokes on alfalfa in the Buckeye Valley, Arizona, 1939–43*

Month	1939	1940	1941	1942	1943	Average
May	9	1	3	0	2	3
June	15	6	11	1	13	9
July	46	21	15	4	140	45
August	6	10	9	11	12	10
September	16	7		23	3	12
October	12	2	2	10		7
November	8	1	0	12	2	5

shelter and others in open fields during the summer. Females comprised 52 to 56 percent in the summer and 55 to 66 percent in the winter. Samples of all the other species were collected during the summer. Females comprised 63 percent of 73 *C. ligata* in 3 samples, 54 percent of 505 *Euschistus impictiventris* in 8 samples, and 53 percent of 655 *Thyanta custator* in 7 samples.

NATURAL ENEMIES

Egg Parasites and Predators

Telenomus utahensis Ashm., a small proctotrypid egg parasite, was the most effective natural enemy of stink bugs in alfalfa during these studies. Late in the summer in some seasons it parasitized up to 66 percent in large collections of the eggs of *Chlorochroa sayi*. It also attacked the eggs of other species. Another parasite, *Ooncyrtus johnsoni* (How.), was reared from stink bug eggs collected in the Buckeye Valley, but it was never more than one-fourth as effective as *T. utahensis*.

Predators destroyed many stink bug eggs. *Collops* sp. was common in the alfalfa fields under observation, and in some seasons it was not unusual to find eggs that had been partially consumed, apparently by some insect with chewing mouth parts. It is probable that entire eggs or egg clusters were destroyed by such predators. Clancy (*3*) reported that in July and August 1937 *Collops marginellus* Lec. destroyed from 28 to 64 percent of *Euschistus impictiventris* eggs in samples observed on cotton in the Yuma Valley near Somerton, Ariz. Stink bug adults often suck the liquid contents from eggs of their own or other pentatomid species, particularly where infestations are heavy.

The percentages of *Chlorochroa sayi* eggs destroyed by parasitic and predaceous insects in samples of eggs collected in alfalfa fields from 1936 to 1942 are given in table 11. The eggs destroyed by all forms of insect enemies ranged from 19 percent in 1942 to 70 percent in 1941.

Table 11.—*Field-collected* Chlorochroa sayi *eggs destroyed by insect parasites and predators, 1936–42*

Year	Samples	Eggs	Eggs destroyed by—		
			Insect parasites	Predators	
				Stink bug adults	Other insects
	Number	*Number*	*Percent*	*Percent*	*Percent*
1936	2	8, 167	40	1	2
1937	4	17, 047	15	16	0
1938	4	45, 657	13	10	6
1939	7	9, 559	30	7	3
1940	6	11, 909	21	14	0
1941	2	1, 586	59	11	0
1942	4	3, 434	10	8	1
Average			27	10	2

Parasites of the Adults

Two tachinid species, *Rhodogyne fuliginosa* (Desv.) and *Cylindromyia euchenor* (Walk.), have been reared from adults of *Chlorochroa sayi* collected throughout southern Arizona and from adults of *C. ligata* collected in the Salt River Valley of south-central Arizona. Larvae of *R. fuliginosa* were dissected from only two adults of *Euschistus impictiventris* out of several thousand examined, and no parasites were reared from adults of this stink bug. No parasites were reared or dissected from adults of *Thyanta custator* or *Acrosternum hilare*.

Rhodogyne fuliginosa comprised approximately 85 percent of the tachinids reared or dissected from adults of *Chlorochroa sayi*, and larvae of both *R. fuliginosa* and *Cylindromyia euchenor* were dissected from adults of *C. sayi* throughout the year. Parasitization was fairly high in adults of *C. sayi* early in the spring, but it seldom exceeded 1 or 2 percent in the later generations during the summer. Late in May 1938 parasitization was 25 percent in a colony of adults of *C. sayi* found on *Sisymbrium irio* near Mesa. Near Safford in May 1940 a heavy infestation of first-generation adults of *C. sayi* on small grains left extremely large numbers of the tachinid parasites behind when most of the stink bugs left the maturing grain. Up to 16 percent of the remaining bugs examined in some of the grainfields were parasitized.

CONTROL

Cultural Practices

Because of the tendency of stink bugs to migrate from uncultivated host plants into fields of cultivated crops and from one crop to another, it is practically impossible to control them entirely by cultural means. Nevertheless, certain farming practices will greatly reduce the likelihood of serious damage to alfalfa-seed crops and may prevent economic injury by these insects. Weed control, adjustments in the layout of crops on farms, proper timing of alfalfa-seed crops, good agronomic practices, and community cooperation may all be utilized in reducing the injury to alfalfa seed by stink bugs.

One of the best ways to prevent the development of harmful populations of stink bugs is to eliminate the habitats that shelter them during the winter and the uncultivated plants upon which they oviposit and feed in late winter and early spring. Fence rows, ditchbanks, roadsides, field margins, and waste land in cultivated areas should be kept as free as practicable of weed growth and dense accumulations of dead plant material or other trash. Straw, unbaled hay, or other plant refuse in fields should be scattered thinly, plowed under, burned, or removed. Weeds in fields should not be allowed to go to seed.

In the warmer areas in Arizona and other Southwestern States some of the important cultivated host plants, notably small grains and sugar beets grown for seed, mature in the spring and are harvested in May or June. Most of the stink bugs in these crops depart when the seed matures or the crops are harvested, many of them going to alfalfa fields, where they aid in building up the infestation in the main alfalfa-seed crop during June and early part of July. These movements into seed alfalfa can be greatly decreased by adjusting the crop layout so as to avoid growing alfalfa-seed crops close to small grains or sugar beets.

To lessen injury by stink bugs, the alfalfa-seed crop in an area should be started as uniformly,

grown as rapidly, and harvested as uniformly as soil conditions, supply of irrigation water, farming program, and available harvesting machinery permit. Approximately 75 days are required to mature an alfalfa-seed crop under favorable conditions in the warm irrigated valleys of Arizona. A crop started about April 15 will usually mature and be ready for harvest early in July, before the peak of stink bug abundance is reached in alfalfa fields. Uniform timing of the crop in all fields in a seed-producing area greatly reduces the volume of stink bug movement from field to field. When the crop is not started and matured rather uniformly in all fields in a district, the bugs often concentrate in the later maturing fields and cause serious damage to the seed.

A fairly light uniform soil, ample and well-distributed soil moisture, and properly timed irrigations are usually required to produce a fast-maturing, high-yielding crop of alfalfa seed in southern Arizona. Loams and sandy loams permit deeper penetration of water and alfalfa roots and promote greater plant stability and seeding capacity than do heavier soils. It is desirable to apply all the irrigation water necessary to produce the seed crop before the alfalfa growth has advanced beyond the early bloom stage. Later irrigations usually cause a second growth of succulent vegetation, which retards seed development and prolongs the seeding period.

The greatest benefits from cultural control measures result when all farmers in a community or district cooperate in applying them. However, where united action is impossible or impractical, the individual farmer can often prevent severe stink bug damage by thorough application of the suggested cultural practices on his own farm.

Insecticide Applications

Tests made in 1935 and 1936 by Cassidy and Barber (*2*) on cotton in Arizona showed that stink bugs and other hemipterous insects could be controlled and yields increased with a sulfur dust containing 7.5 percent of paris green. Three applications of this dust at 2-week intervals during June 1937 to seed alfalfa at the rate of 10 pounds per acre reduced stink bug populations 97 percent. However, the treatments caused the alfalfa flowers to wither and fall prematurely.

In 1938 a dust containing 14 percent of flotation sulfur, 20 percent of milled sulfur, and 0.2 percent of pyrethrins, applied at the rate of 20 pounds per acre, and an oil spray containing 0.056 percent of pyrethrins, applied with an air-blast sprayer at the rate of 4 gallons per acre, were both ineffective against stink bugs. In 1945 single dust applications of DDT at ¾ to 2½ pounds of the active ingredient per acre, and of sabadilla at 5 pounds of the ground seed (sabadilla alkaloids 2 percent) per acre, in the late-bud to early-bloom stage of development did not effectively control stink bugs. During 1946 studies were continued with nine formulations of insecticide dusts, and the greatest reduction in populations was 56 percent on plots treated with a mixture of 1¼ pounds of DDT and 2½ pounds of ground sabadilla per acre.

The insecticide formulations and dosages tested against stink bugs from 1938 to 1946 were either ineffective for economic control or caused injury to the alfalfa flowers. Better results were obtained with some insecticides tested from 1947 to 1949. Unfortunately, for these later tests stink bug populations were extremely low in most fields, so that it was often impossible to find fields suitable for conducting reliable tests.

In tests conducted from 1947 to 1949 on mature seed alfalfa, good to excellent kills were obtained with fairly high dosages of chlordane, benzene hexachloride, and parathion, and with mixtures containing DDT plus lindane, chlordane, or toxaphene. Sprays and dusts were applied with ground equipment, except in an 80-acre field, where the parathion was applied by airplane. The results obtained with these treatments are given in table 12. In other tests reductions in population of 93 to 95 percent were obtained with 4⅙ pounds of benzene hexachloride (12 percent gamma) per acre applied in a suspension spray, a mixture of 1¼ pounds of DDT and 2 pounds of chlordane in an emulsion, and ½ pound of parathion in a dust.

Because of extremely low stink bug populations on prebloom alfalfa and to avoid killing honey bees and other pollinating insects during the blooming period, the higher dosages of chlordane, toxaphene, and benzene hexachloride were not tested for stink bug control on immature seed alfalfa. Chlordane at 1 pound and toxaphene at 1½ to 2 pounds per acre, dosages that usually give high kill of lygus bugs and grasshoppers in tall green alfalfa, did not control stink bugs.

Twenty-five pounds per acre of a dust containing 1¼ pounds of DDT and 4⅙ pounds of benzene hexachloride (12 percent gamma) applied by airplane killed 90 to 100 percent of the stink bugs in flax, and doubtless would also be effective in alfalfa.

Serious stink bug infestations can rarely be predicted sufficiently in advance of alfalfa blooming to permit timely application of insecticides. When it is possible to predict such an infestation, it is unlikely that a treatment applied before blooming begins would have enough residual effect to control the bugs that move into or hatch in the field during the blooming and seed-

TABLE 12.—*Results of field tests with various insecticides for control of stink bugs on mature seed alfalfa in the Salt River Valley, Ariz., 1947–49*

Insecticide	Dosage of active ingredient per acre	Size of field or plot	Stink bugs	
			Average per 100 net strokes	Reduction 3 days after treatment
Dusts (25 pounds per acre):	*Pounds*	*Acres*	*Number*	*Percent*
Benzene hexachloride (2 percent gamma)	[1] ½	1	86	85
Parathion	½	4	180	89
	½	80	34	94
DDT	1¼	4	300	87
Lindane	½			
Emulsion sprays (10 gallons per acre):				
Chlordane	4	¼	76	87
DDT	1¼	¼	76	93
Chlordane	2			
Toxaphene	4	¼	76	62
DDT	1¼	¼	76	84
Toxaphene	2			

[1] Gamma isomer.

forming periods. If insecticidal treatment is delayed until the blooming period is over, it is usually too late to prevent the greater part of the stink bug damage to an alfalfa-seed crop.

CAUTION

Forage or chaff contaminated with DDT, chlordane, toxaphene, benzene hexachloride, or lindane, should not be fed to dairy animals, to meat animals being finished for slaughter, or to poultry. Alfalfa treated with parathion should not be fed prior to 14 days after treatment. To avoid killing honey bees and other pollinating insects, poisonous materials should not be applied while the alfalfa plants are in bloom except to prevent severe seed damage. If control during the blooming period is essential, only toxaphene should be used and the applications made after 7 p. m. or before 7 a. m., while bees are inactive in the field.

SUMMARY

A study of stink bugs in relation to alfalfa-seed production was made in southern Arizona, during the period 1935–49. This study showed that the nymphs and adults cause economic injury by sucking the liquid contents from the immature seed.

Stink bugs collected on seed alfalfa from 1936 through 1943 ranged from 0.01 to 0.19 per net stroke in different years and averaged 0.07 per net stroke for the entire period of study. Annual seed damage ranged from less than 1 to 15 percent and averaged approximately 6 percent. Seed damage in three of the most heavily infested fields in 1937 averaged 28, 36, and 77 percent.

Chlorochroa sayi Stål was the dominant species in alfalfa. Other species of importance were *Euschistus impictiventris* Stål and *Thyanta custator* (F.).

Important host plants of stink bugs include alfalfa, cotton, seed beets, grain sorghum, barley, alfileria, *Sisymbrium irio*, Australian saltbush, mallow, globemallow, nettleleaf goosefoot, and careless-weed. *Chlorochroa sayi* alone was collected from more than 50 plant species.

About 5 weeks were required in summer and 7 to 8 weeks in spring and fall for *Chlorochroa sayi* and *Thyanta custator* to complete their life cycle from egg to adult. Females of various species laid on an average 60 to 151 eggs in 24 to 29 days. Adults usually lived 40 to 60 days in spring and summer, but some overwintering adults lived 7 to 9 months. In southern Arizona stink bugs pass the winter in the adult stage. A favored winter habitat is under a low, creeping branch of Australian saltbush.

The overwintering adults go to spring host plants from early March to mid-April. Most of the eggs of these females are laid on weeds and the nymphs develop on the weeds, some of the more advanced ones usually reaching the adult stage late in April or early in May. Most of the adults soon leave the drying weeds and go to cultivated crops. Adults of the second generation appear about the middle of June, and those of succeeding generations at 5- to 6-week intervals until the last of September.

The peak period of stink bug abundance in alfalfa usually coincides with the developing period of the main seed crop during the latter half of June and the first half of July, when greatest damage is caused. Damage is particularly heavy in fields where the seed crop is late.

The most important natural

enemies of stink bugs observed were *Telenomus utahensis* Ashm., an egg parasite, and *Rhodogyne fuliginosa* (Desv.), a parasite of the adults.

Destructive populations of stink bugs in seed alfalfa can usually be prevented by (1) destroying weeds or dead plant material that provide adult bugs with winter shelter, (2) controlling weeds late in the winter and in the spring in and surrounding seed-alfalfa fields, (3) growing seed alfalfa as far removed as practicable from fields of sugar beets or small grains, (4) starting and harvesting the seed crop on uniform dates in all fields in a community or area, and (5) growing the seed crop as rapidly as good agronomic practices permit. Applications of rather high dosages of chlordane, benzene hexachloride, or parathion, and mixtures of DDT with chlordane, toxaphene, or benzene hexachloride gave fair to excellent kills of stink bugs.

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